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16. Abstract This article is a discussion by Mr. A. V. Sidorenko of the great significance space studies are contributing to all Earth sciences. He mentions geography, geodesy, cartography, geology, meteorology, oceanology, agronomy, ecology and others. He predicts cosmonautics will result in a revolution in science and technology.			
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EARTH STUDY FROM SPACE

A. V. Sidorenko



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When the first space ships were launched, naturalists who worked with the Earth's natural processes, and even those of us who commanded various long-distance aerological methods

* Numbers in margins indicate foreign pagination.

for studying the Earth, thought that cosmonautics is a sphere of the physico-mathematical and technical sciences. At that time we had little idea that space flights would have such a great influence on the natural sciences. However, a very short time has passed, and we saw what a huge significance space studies had for modern geography, geodesy and cartography, geology, meteorology, oceanology, the study of water resources, the study of the vegetation cover, agronomy, ecology, and many other directions of scientific and economic activity. In short, the results of the flights of space apparata -- both manned and automatically operating -- have a significant influence on all Earth sciences.

Studies from space of various natural phenomena, objects and processes have yielded so much which is new in principle for the natural sciences that we may speak of a new stage of their development. Such new concepts are emerging as space mapping, space geology, space oceanology, space dry-land hydrology, etc. This very fact stresses the point that space studies are leading to basic changes in the natural sciences. However, the influence of the new technology is expressed not only in each natural science taken individually, but also on all of the natural sciences taken as a whole.

The great visibility of the Earth's surface from space and the capacity for its simultaneous observation under various physical conditions open a series of new phenomena

for the researcher. Primarily apparent is that which we now call the indicator integration effect, i.e., during observation from space individual dispersed elements on the Earth's surface take on a certain regularity in their location. It has become possible to scan the depths of dry land and the ocean from space. Of significant importance for research is the possibility of simultaneously observing rapidly progressing processes in the atmosphere, the hydrosphere, and the Earth's soil-vegetation covering.



Sources of forest fires and burned-out areas of vegetation in Western Siberia.



Murky waters being emptied into the Black Sea. The photo may be used for evaluating detrital deposit.

Photos are from sputniks of the "Meteor" system, published in the journal "Issledovaniye Zemli iz kosmosa", 1980, No. 2.

All this creates new favorable preconditions for the development of natural science by methods of long-range Earth probe from space. The natural sciences take on a new character, since cosmonautics gives them new methods of study, opens new horizons for the development of science, and makes it

possible to go from a descriptive expression of facts and phenomena to precise qualitative and quantitative evaluations. We have the right now to speak of nature study and earth study conducted from space.

The new stage in the development of natural science is not accidental. It has been prepared for by the entire course of development of science and technology. On the whole, the conditions for the transition of natural science into a new state may be formulated as follows.

1) Man or the apparatus which he has created for research have exceeded the Earth boundaries; the area of space around the Earth is being systematically assimilated, and expeditions to other planets are being sent regularly. It has become possible to see the Earth in an overview from afar, to encompass it with a single glance. This has convincingly demonstrated how small our Earth is in the Universe, and how unevenly mastered it is by man, how vulnerable is nature and how important now is the new development of natural science.

2) In turn, the level of development of natural sciences has now become different. Natural sciences have long since passed from inventorization and description of individual phenomena and processes in nature to the establishment of laws of development of a natural object which are common

to the given science. The number of apparata has sharply increased in Earth studies, and more and more information is being expressed by numbers and measures.

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3) The information which is obtained as a result is reaching such a volume that it can be processed only by new automated means with the utilization of mathematical methods. This makes it possible to rapidly operate with large volumes of information.

4) Mankind is beginning to realize more and more the limitation of natural resources of the planet Earth, and at the same time is experiencing an ever increasing need for them. Thus arises the necessity of taking from nature in such a way as to satisfy the needs to a maximal degree while inflicting minimal damage to nature.

All this taken together presents new problems for natural scientists and requires that they make sense of the modern state of development of natural science at a new frontier of development in human thought. It seems to us that the time is ripe for elevating our study of the Earth to a new level, and particularly such a complex study as Earth science.

Before, Earth science¹ meant the division of physical geography which studied the earth's geographical shell in the most general specifics of its composition, structure,

¹ The term was introduced by the German geographer K. Ritter (1779-1859).

and development. However, the rapid development of the natural sciences at the end of the last century and the first half of this century has lead to their great differentiation and has disrupted the ties within the sciences. /6



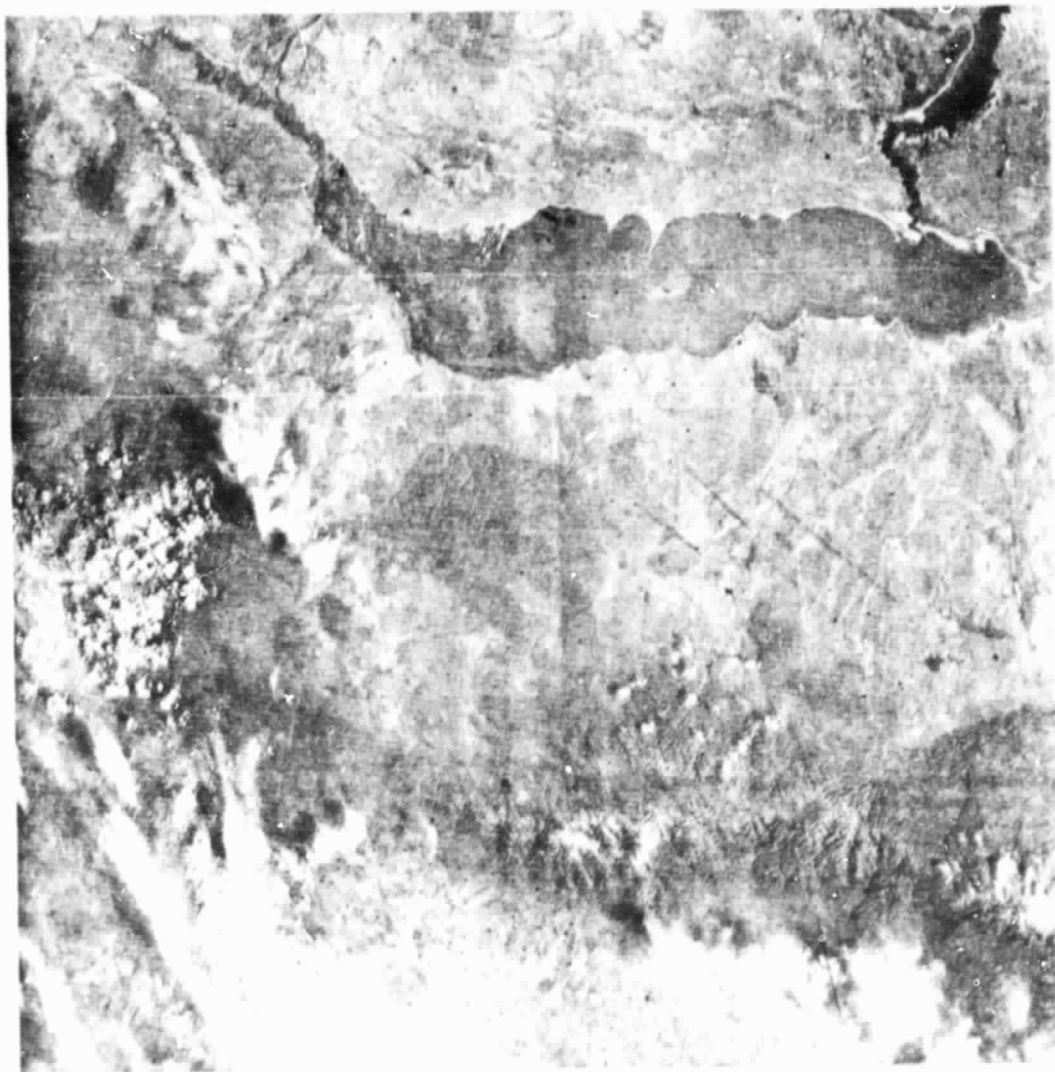
The Ob inlet. Thanks to the clear illustration of the hydrographic network, this photo may be used for defining more precisely the overall area of the water collection basin, the density and extent of the network of small rivers. /5



Central Kamchatka. The hydrological network and the large breaks in the earth's crust are clearly visible. The photo is used for clarifying the geological structures of the region.

Natural science has been deprived of the possibility of examining many earthly phenomena as a whole. But our planet developed over a period of 3.5 billion years as a single

whole -- with its atmosphere, hydrosphere, lithosphere, and biosphere. A cosmic overview of the Earth has given us the opportunity to examine natural bodies, processes and phenomena as a single whole with the interaction and interdependence of natural processes, i.e., to return to earth science, but on a new basis -- space earth science.



Lake Zaysan in Eastern Kazakhstan. Taken from a height of

350 km. The photo was taken on board the space station "Salyut-4" by cosmonauts P. I. Klimuk and V. I. Sevast'yanov.
TASS Photo Chronicle.

By this we mean the discovery by space methods of natural processes of the planet Earth in their interconnection, interdependence, and dialectic unity and contradiction.

Space earth science studies by long-range methods the interconnection and interdependence of phenomena and processes occurring in the atmosphere, biosphere, and lithosphere of the earth. We would like to stress once again that space earth science presupposes a unity of long-range and contact methods. Phenomena which are determined from space must always be confirmed by studies conducted on earth. In application to the study of natural processes on Earth, a rather encompassing term has come into use -- "the earth-space hierarchy". It includes the complex of earth study from space, from high altitude and low-flying apparata, as well as the de-coding of the obtained images, accompanied whenever necessary by geophysical and drilling research into the depths of the continent, and for the ocean -- by a complex of depth sounding of the hydrosphere. /2

Space earth science is not space nature study. We understand the latter to be a wider science, which includes not only the earth, but also all of nature as a whole. Space earth science, as we understand it, is one of the fundamental sciences studying earth processes directed

ultimately toward meeting the needs of mankind.



The Sargassovo Sea in the region of the Andros Islands.

Taken from an altitude of 350 km. The photo was taken by cosmonauts G. M. Grechko and Yu. V. Romanenko on board the space complex "Salyut-6" - "Soyuz".

TASS Photo Chronicles.

As with any science, space earth science has its methods and research goals. As we have already said, the main research method of space earth science is the combination of the entire multitude of long-range methods with studies conducted on earth. /8

The goals of this new science may be generalized as follows.

The integration of regularities of all natural sciences studying the Earth (space geology, oceanology, geography, ecology, etc.) in order to establish regularities of the general processes taking place in the atmosphere, hydrosphere, lithosphere, and biosphere of the Earth, the discovery of the interdependence and interconditionality of these processes and phenomena. Undoubtedly in the future the formulations of goals, tasks, as well as the research methods themselves will be clarified and developed.

Let us clarify this thought. The farther space earth science progresses, the more we begin to understand the interdependence between in-depth processes taking place within the depths of the earth or the ocean and the processes taking place at their surface, and the more we become convinced that the Earth's surface, as well as the surface of the ocean, evidently reflect deep-seated processes which are taking place within the depths of the planet and which are preconditioned by the entire course of the long-term evolution

of the earth's crust.

We are beginning not only to understand the interconnection between natural phenomena on Earth, but also to rank (classify) them by their degree of importance, interdependence, and priority.

We could give numerous examples of this interconnection and interdependence. Based on my geological experience, I will give only one example of the dependence of the geological structure of relief, soils, vegetation, surface water regime, on deep-seated processes within the Earth's core.

It has long been established that the earth's lithosphere has a flexible structure, and consists of individual blocks of different rank. Block uplifting, arising as a result of deep-seated tectonic processes, determines the geomorphological specifics of the earth's surface, its relief, the vegetation and hydrological regime, and following this -- the distribution of vegetation and biogeocenosis. This is beautifully expressed in the interrelation of the earth's vegetation covering with the soil, hydrogeological, and geological structures of each large earth block. Such a dependence has been proven for the Subarctic region, the Taiga, Siberia, the deserts of Central Asia, and the plains of the European portion of the country. The cause and effect dependence between two dialectically opposed processes: deep-seated endogenous processes taking place within the

depths of the earth and processes which are conditioned by climatic conditions, which are reflected in the character of the relief, in the soil, humidity, vegetation -- has been established earlier. However, it is especially clearly evident thanks to research conducted from space.

For example, on a fault map for the territory of the USSR it is clearly evident that the hydrographic network of the continents is a direct result of deep-seated geological processes taking place within the depths of the planet. River beds -- particularly large ones, are a reflection of the earth's fault tectonics. All the major rivers flow along fault zones. Seismically active regions are located in certain fault zones. Most large lakes arise in places where large blocks have sunk down. Mountains are a result of intensive tectonic processes, folding and uplifting, i.e., the result of deep-seated processes. Considerable areas of valleys and sometimes also bogs are formed on individual earth blocks which have had a long-time stable position.

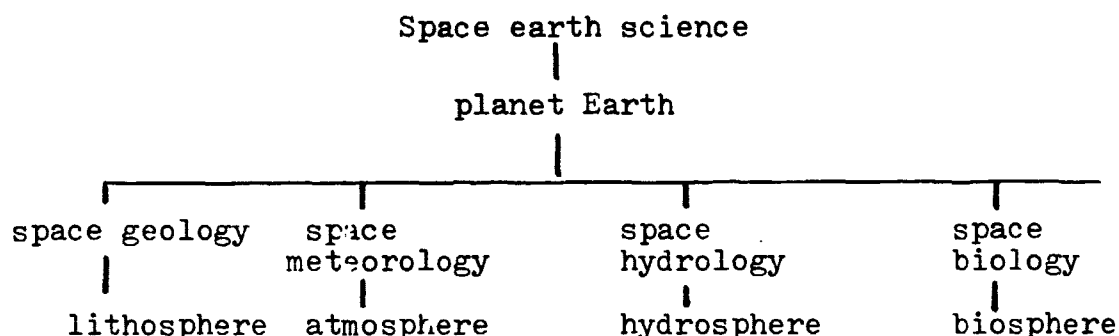
The earth's relief is conditioned by the interactions of the earth's external and internal forces. Climatic conditions superimposed over relief determine the distribution of moisture, vegetation, i.e., that which we call topography.

The connection between the geological structure of individual sections of the earth, which is conditioned by

geological processes, surface relief created by a combination of endogenous and exogenous processes in certain natural-climatic zones, by the distribution of underground water, and by the distribution of plant and animal life, has long been known in its general aspect. However, large collectives of natural scientists spent several decades of work in discovering this interdependence, while the cosmic view, space images make it possible to realize this regularity in several tens of turns around the Earth. Now this general regularity of the connection between various elements of the earth's surface must be developed, detailed, and quantitative and qualitative regularities must be sought within it on the basis of new space information in the form of photographs or other images of all these topographical elements.

The possibility is not excluded that we will soon find a connection between the earth's physical properties and the distribution of atmospheric phenomena on its surface. /9
Statistical data on the recurrence frequency of cloudiness of varying degrees of intensity over certain parts of the earth -- deserts, polar and mountain regions, and even fault zones and zones with anomalous gravitation -- is already beginning to accumulate. The determination of connections between atmospheric phenomena and geological structures and climatic zones is fully probable, since space research makes it possible to study processes which

occur simultaneously and rapidly, while automated processing systems make it possible to process large volumes of information.



There are sufficient examples proving the usefulness of space methods for earth study. It is time to go from individual examples to planned complex studies of natural phenomena and processes. It seems to us that great possibilities are opened up here. The automated processing of space images with the application of mathematical methods makes it possible to express in mathematical language the relationship between various elements of the face of the earth and to show the role of geological, geomorphological, biogeological and other processes which created the modern earth surface. And from quantitative evaluations of one or another natural phenomenon on the surface we may go to an evaluation of the speed of its passage and duration, i.e., in the final evaluation we may obtain an equation for natural processes, we may discover their regularities and make pre-

dictions.

This it seems to me is the main purpose of space earth science. I, as a geologist, examined the new direction in natural science -- space earth science -- primarily from the position of a geologist, seeking a connection between geological, soil, and biological processes. However, the organization of other no less large and important problems is possible. Experience has shown the necessity of developing space methods in application to agriculture, reclamation, and fish management.

Space earth science appears to me as a science consisting of two or three levels of knowledge, with the classical earth sciences serving as its base -- geology, geography, ecology, oceanology, etc. At the next stage these sciences take on space methods and become space geology, geography, ecology, and oceanology. The integration of conclusions from these individual space earth sciences gives a new scientific direction -- space earth study, which becomes the apex of the pyramid of earth sciences.

There was a time which was called the time of great geographic discoveries. Thanks to cosmonautics, and the development of space research into the Earth and the Universe, it seems to us that we must speak of the age of space earth study, which will give us still more great new discoveries.

We are entering into an age of great space discoveries in nature.

I would like to conclude with the same idea with which I began. In starting to conquer space, we thought that this is primarily a technical problem, but time has shown us that cosmonautics is not only a child of the scientific-technical revolution. Cosmonautics has itself laid the beginnings of a revolution in natural science. Thus, the knowledge of technical and natural science merge into a single process at this new stage, and in this we see the great future development of human thought.

In almost all directions of human knowledge, cosmonautics is now making such radical changes that we have reason to speak of a space revolution in technology and science. Evidently we have not yet fully realized the new stage of knowledge to which cosmonautics is leading us, and have not yet made the corresponding conclusions.